DISPLAY METHODS FOR GEOGRAPHIC DATA SETS

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ABSTRACT

A pixel based contouring algorithm is described and used to display three sample world wide data sets. The use of contouring, color coding and hill shading is discussed and related to the spatial frequency content of the data. Contouring has problems in steep areas where the contour lines run together. Color coding brings out the low frequency content of the data. Hill shading brings out the high frequency content or texture. Color coding and hill shading may compliment each other when the data has a mixed high and low frequency content.

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INTRODUCTION

One purpose of a map is to convey spatial information. A number of techniques may be used exclusively or in combination to produce the map. The techniques illustrated in this paper include contouring, color fill, and shading. The success of these techniques in conveying the desired information is closely related to the number of colors available on the display device and the frequency content of the data set.

ALGORITHM DESCRIPTION

The following display algorithm incorporates the techniques of contouring, color fill, and shading. The database is first sampled such that each pixel on the display device has a corresponding data value. Then:

```
1  for each y
2    for each x
3      if the contour interval is not 0
           then compute an integer
           contour number.
4      if the contour interval is 0 or
           the contour number has changed
           from pixel to left or below then
5        scale the pixel's data value
             into a hue,
6        compare slope against a shade
             threshold to determine shade,
7        color the pixel.
```

Steps 1 and 2 generate the loops necessary to cover the display area one pixel at a time. The contour number in step 3 is computed by dividing the contour interval into the data value. If the contour interval is 0 then the contour number is undefined. Step 4 determines if the pixel is to be turned on. Step 5 determines the color. Step 6 does simple hill shading. Pixels where the slope is downward in the direction of illumination are light shaded. Pixels where the slope is upward in the direction of illumination are dark shaded. Step 7 turns on the pixel.

The algorithm generates contour lines when the contour interval is not zero and filled maps when the contour interval is 0. It color codes the pixels according to data value if colors are available. If the shade threshold is small then the pixels will be hill shaded. Thus the algorithm incorporates:

1) contouring
2) color coded contouring
3) hill shaded contouring
4) color coded hill shaded contouring
5) color coded fill
6) filled hill shading
7) color fill with hill shading

DISPLAY DEVICE DESCRIPTION

The above algorithm was implemented on an IBM compatible PC with the Enhanced Graphics Adapter (EGA). This system offers 16 viewable colors and a screen resolution of 640 pixels in x and 350 pixels in y. Figures 1-12 were photographed from the screen of this display device.

DATABASE DESCRIPTION

Three databases were chosen for illustration which differ markedly in frequency content. The magnetic field intensity provided by the Naval Oceanographic Office (1) contains only low frequency information. The gravity free air anomaly was computed at degree 180 from a spherical harmonic model provided by Ohio State University (2). It has mostly a high frequency content. The bathymetry data provided by the Naval Oceanographic Office has both a high and low frequency content.

MAP DESCRIPTIONS

The following maps were generated on the PC using the above algorithm and databases in order to illustrate the interactions between the display technique and the database frequency content. For each of the 3 databases, 4 mapping techniques are illustrated. The techniques are:

1) contouring
2) hill shading
3) color fill
4) color fill with hill shading.

Unfortunately these proceedings are printed in black and white so the colors appear as shades of gray. All of the maps are linear in latitude (-80 to +80 degrees) and longitude (0 to 360 degrees). The illumination for the hill shading is from the right.

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The first set of 4 maps show the total intensity of the magnetic field computed from a low degree and order harmonic model. High intensities are associated with the North and South Magnetic Poles. The intensity is low near the equator.

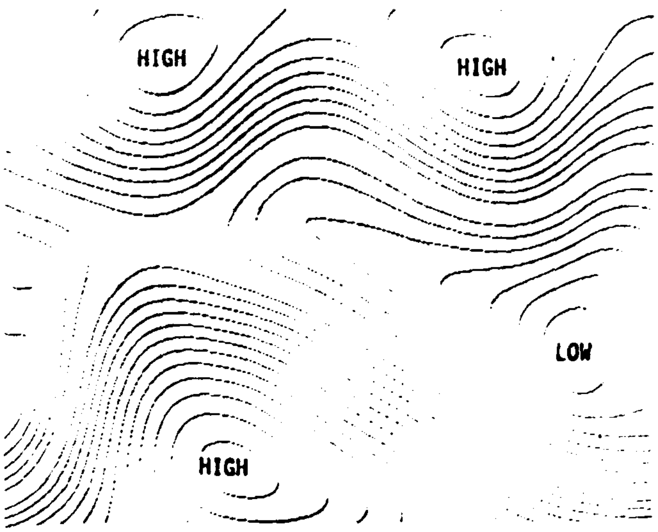

Figure 1. The Magnetic field intensity contoured. Contouring works here because, due to the smoothness of the data, the contour lines do not run together.

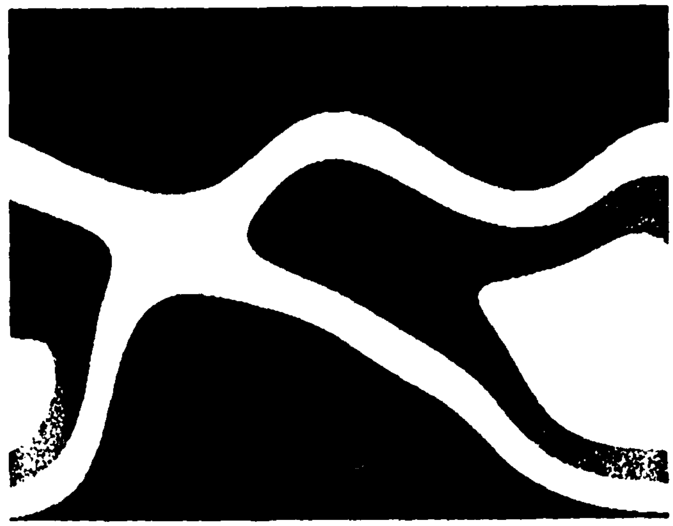

Figure 3. Magnetic field intensity color coded. This technique works very well with low frequency data. If colors are chosen in rainbow order the highs (red) and lows (blue) are naturally identified. The resolution is limited by the number of discernable colors provided by the display device.

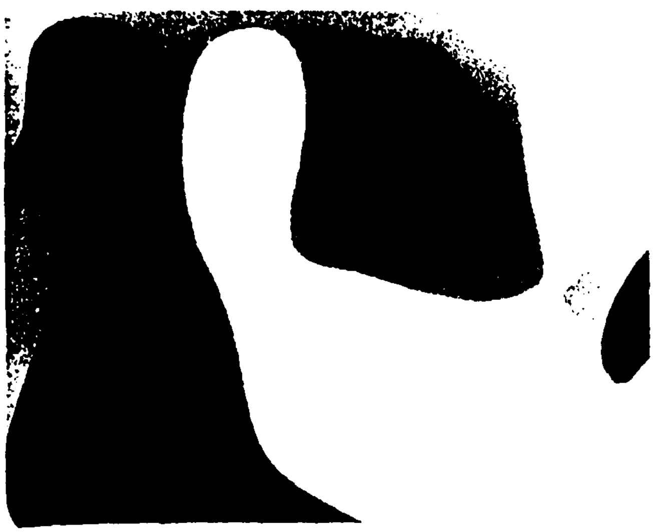

Figure 2. Magnetic field intensity hill shaded. The light areas slope downward toward the east. The dark areas slope upward toward the east. Hill shading is inappropriate here since there is no high frequency texture to bring out. The areas of high gradient are clearly identified, but the casual viewer may not make the correct interpretation.

Figure 4. Magnetic field intensity color filled and hill shaded. Hill shading has nothing to add and only detracts from the image unless it is necessary to identify areas with a high slope.

Figures 1-4 show that contouring and color coded fill are the best methods for data that has only a low frequency content. Contouring has the advantage that the number of contours is not limited by the number of colors available on the display system. Highs and lows must be identified in some manner. Shading is generally not appropriate unless high frequencies are present.

The next set of four maps show the gravity free air anomaly field. This data set is dominated by a high spatial frequency content primarily associated with the subduction zones surrounding much of the Pacific Ocean.

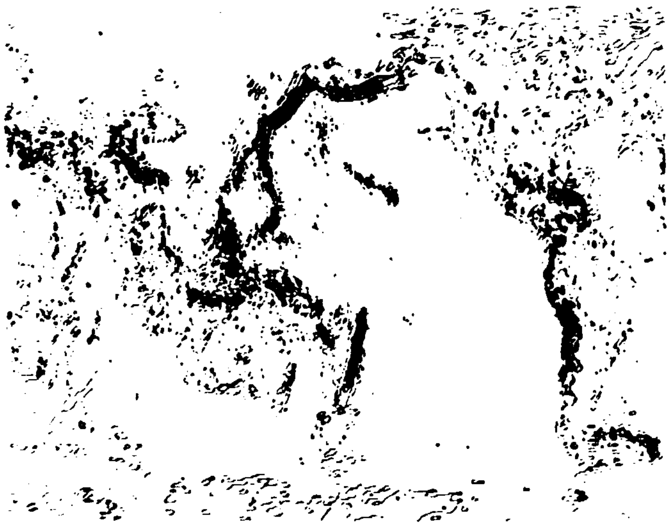

Figure 5. Gravity anomaly contoured.
The contour lines run together where there is a steep gradient. It is obvious that something is happening but it is not clear just what.

Figure 7. Gravity anomaly color filled.
Color fill brings out only the high amplitude changes. The fine texture is lost.

Figure 6. Gravity anomaly hill shaded.
Hill shading brings out the high frequency information.

Figure 8. Gravity anomaly color coded and hill shaded. The color coding compliments the hill shading to bring out the small but possibly significant low frequencies while still revealing the texture.

Figures 5-8 point out a weakness of contouring when applied to a data set containing high amplitudes in the higher spatial frequencies. The contour lines run together. Hill shading is a much better method of showing texture.

The last set of 4 maps show bathymetry. Here we have a mixture of both high and low spatial frequencies.

Figure 9. Bathymetry contoured. Information is lost in steep areas where the contour lines run together.

Figure 11. Bathymetry color filled.
The major features are revealed but the fine texture is lost.

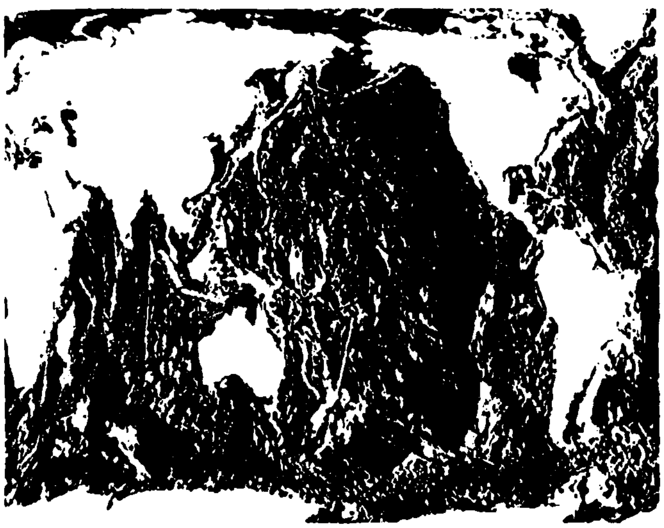

Figure 10. Bathymetry hill shaded.
The sea bottom texture is brought out nicely using only 3 shades.

Figure 12. Bathymetry color filled and hill shaded. The color coding and hill shading work together to emphasize the major features while also revealing the fine texture.

Figures 9-12 show that shading and color coding can be effectively used together when the data has mixed spectral content. Hill shading brings out the high frequencies. Color coding brings out the low frequencies.

CONCLUSIONS

The techniques of contouring, color coding, filling, and shading can all be combined into one simple algorithm. (Fortran and C implementations were about one page long.)

Contouring and color coded fill are appropriate for data sets having mostly low spatial frequencies. The number of discernable fill colors on a particular display device may limit the resolution of the color coded fill method but not the contouring. Contour maps need to have highs and lows identified in some way, either using color coding of the contour lines or labels. Contour lines tend to run together if the data contains a high frequency component of sufficient amplitude.

Hill shading brings out high frequency information in a very clear manner.

Hill shading may be effectively combined with color coding when the data set contains a mixture of spatial frequencies.

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